Energy Sustainability as a Global Imperative

Presented at iCAST Colorado Tech Week

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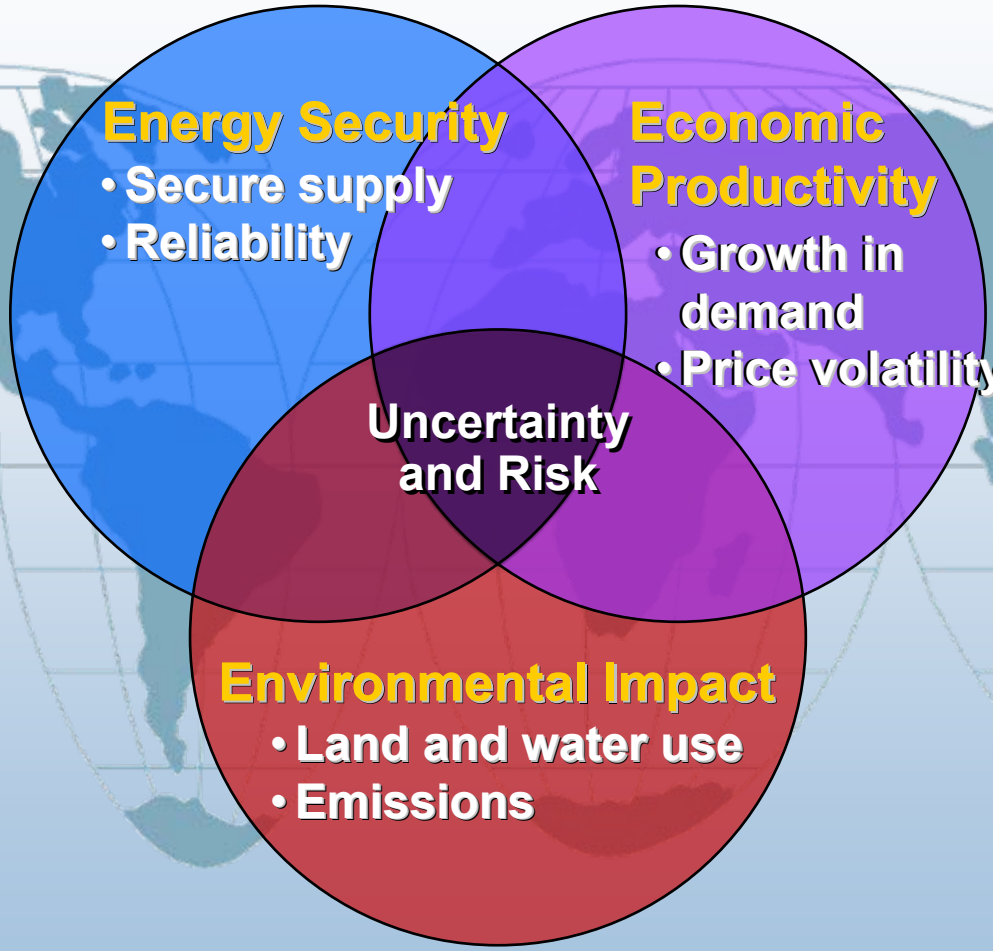
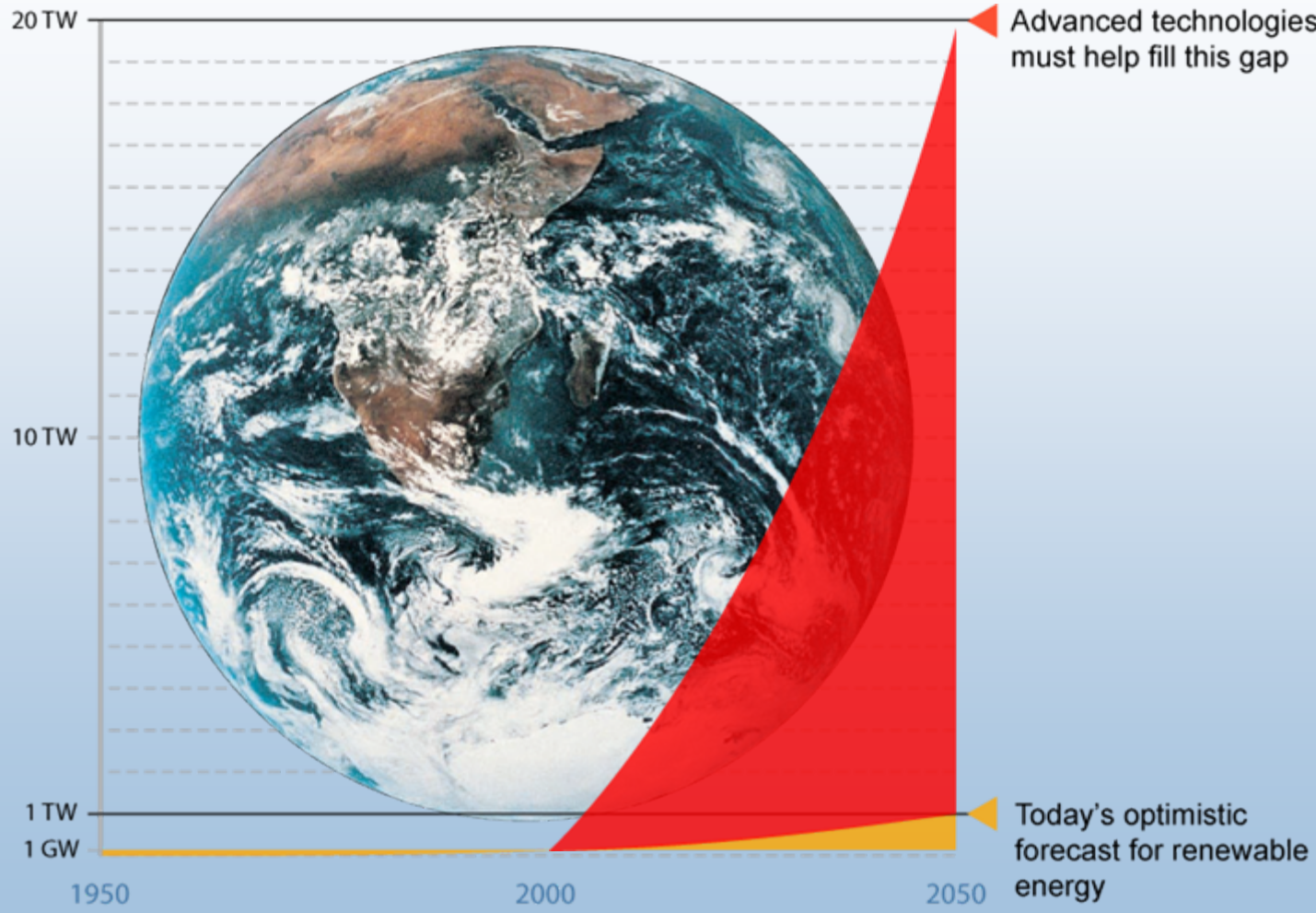
Energy Solutions Are Enormously Challenging



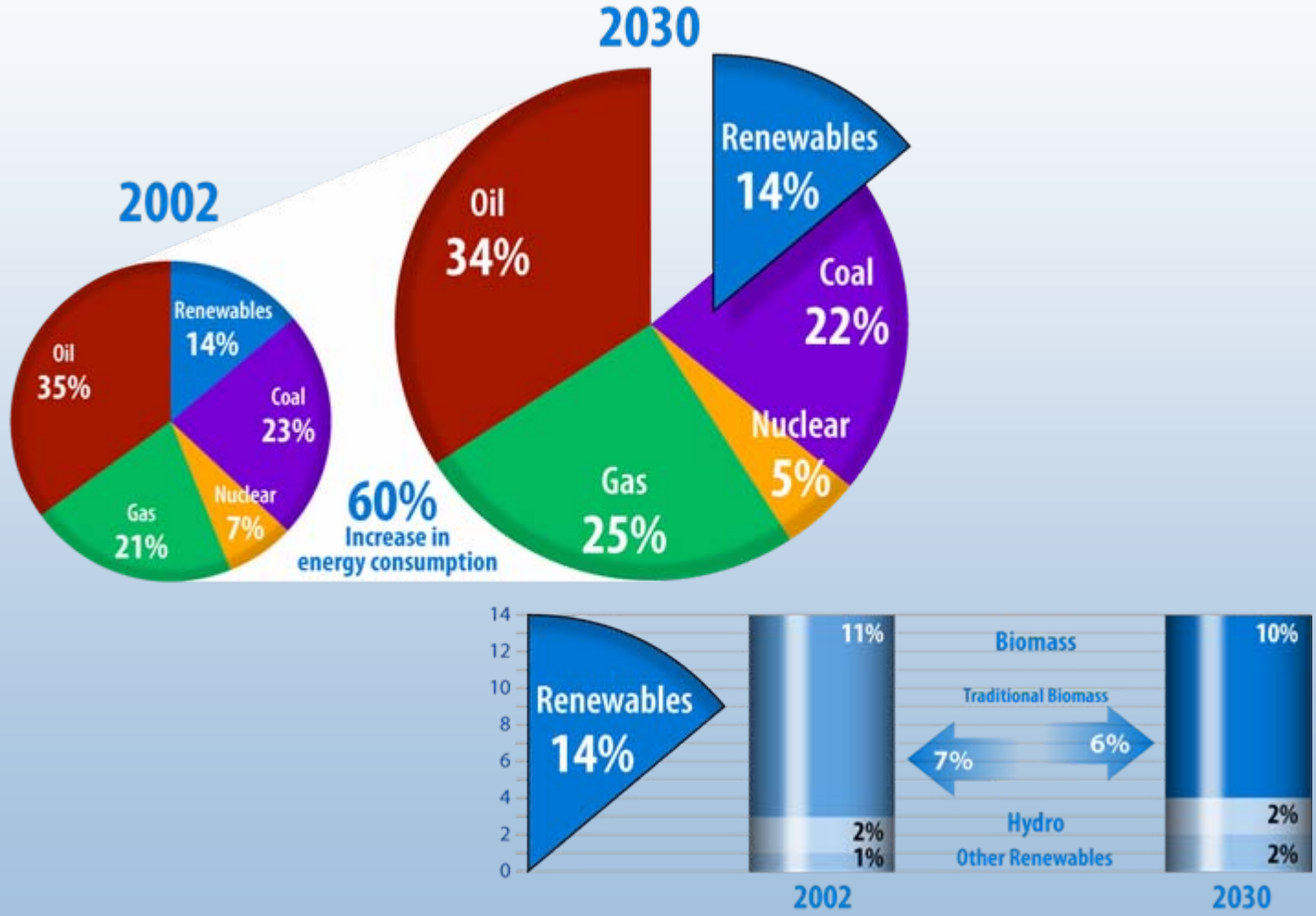
We need a balanced portfolio of options

Magnitude of Challenge Requires Global Action and a Change in Trajectory



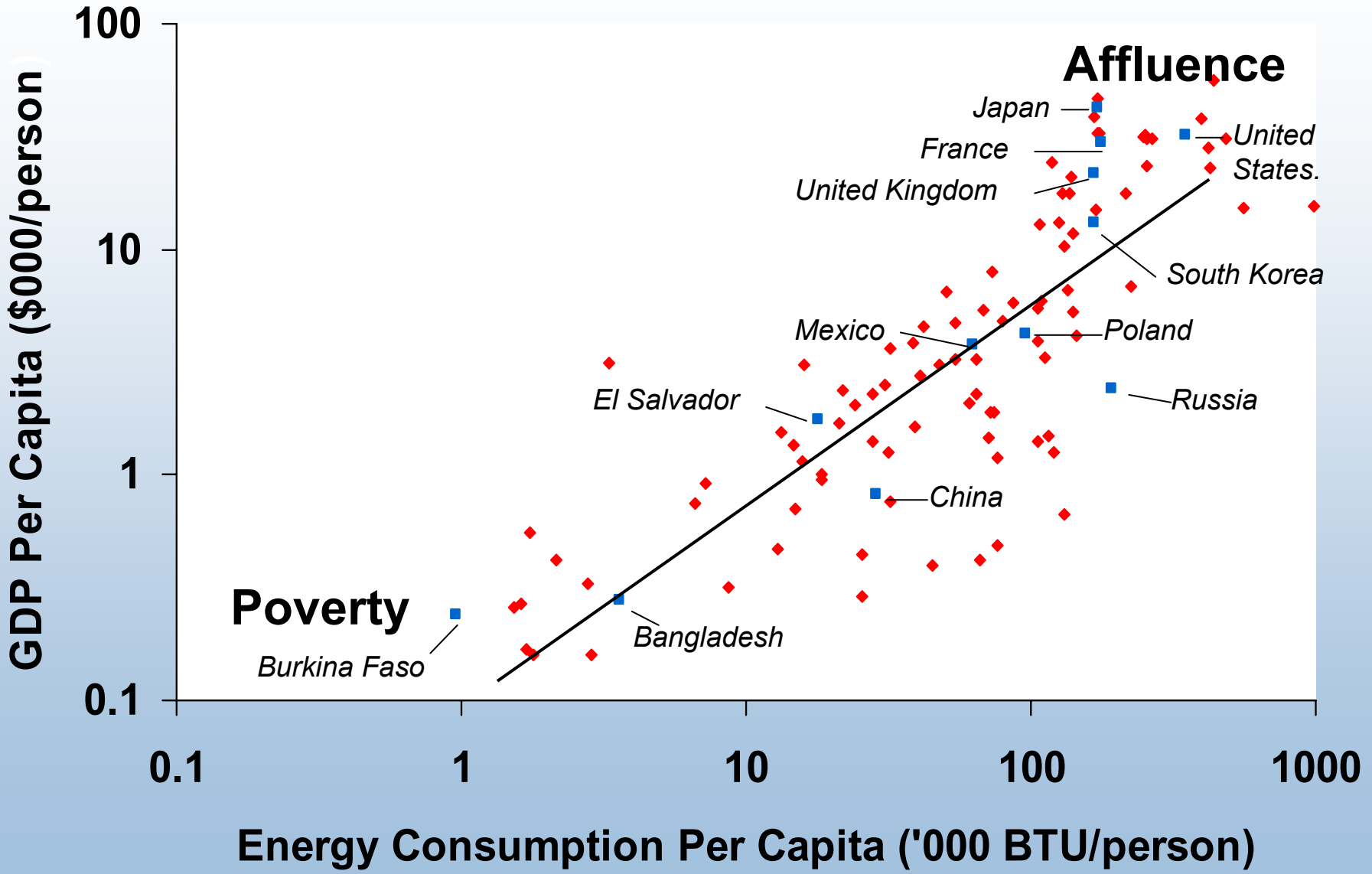
Source: Arvizu, NREL

World Energy Supply and the Role of Renewable Energy



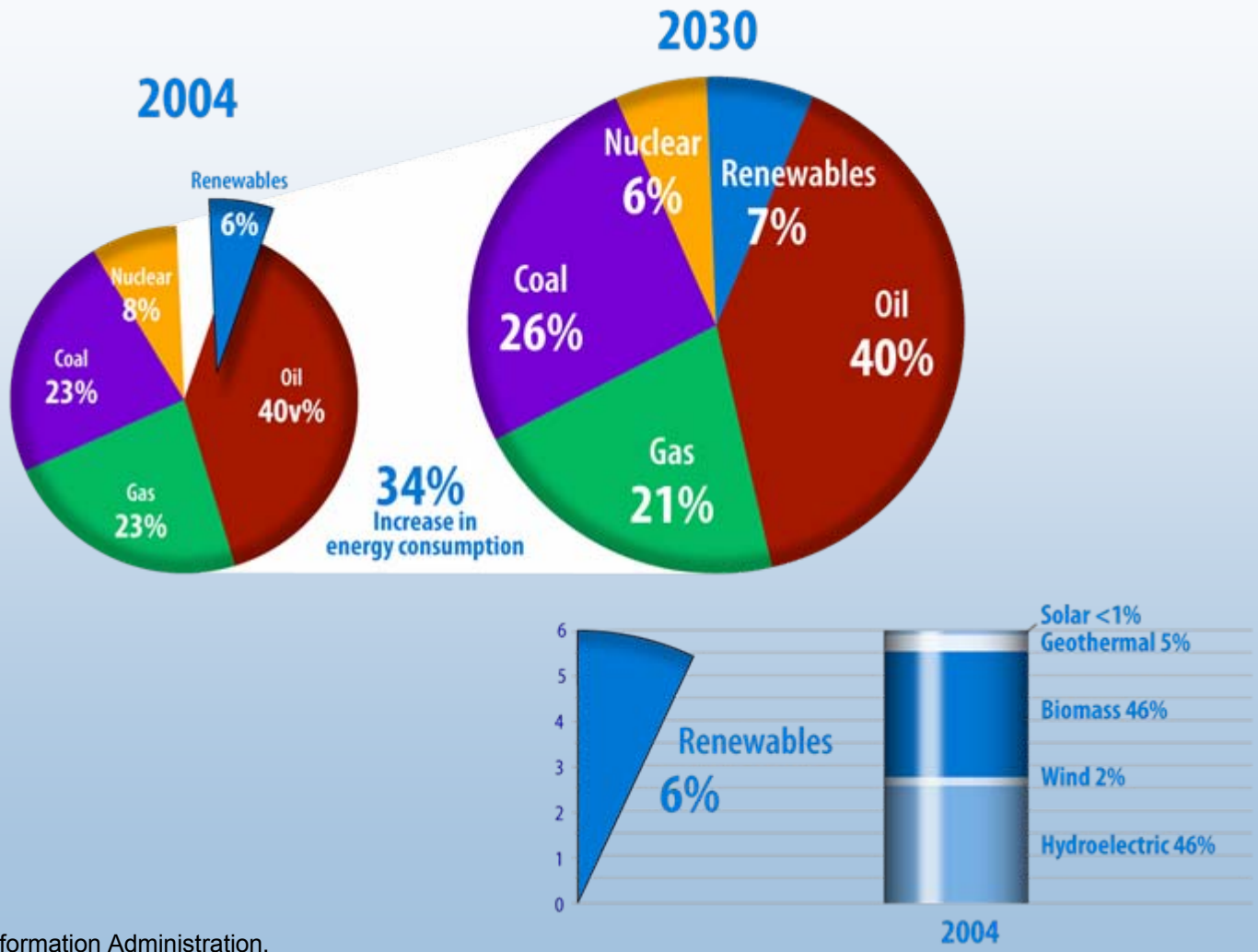
Source: OECD/IEA, 2004

Energy Use and Gross Domestic Product



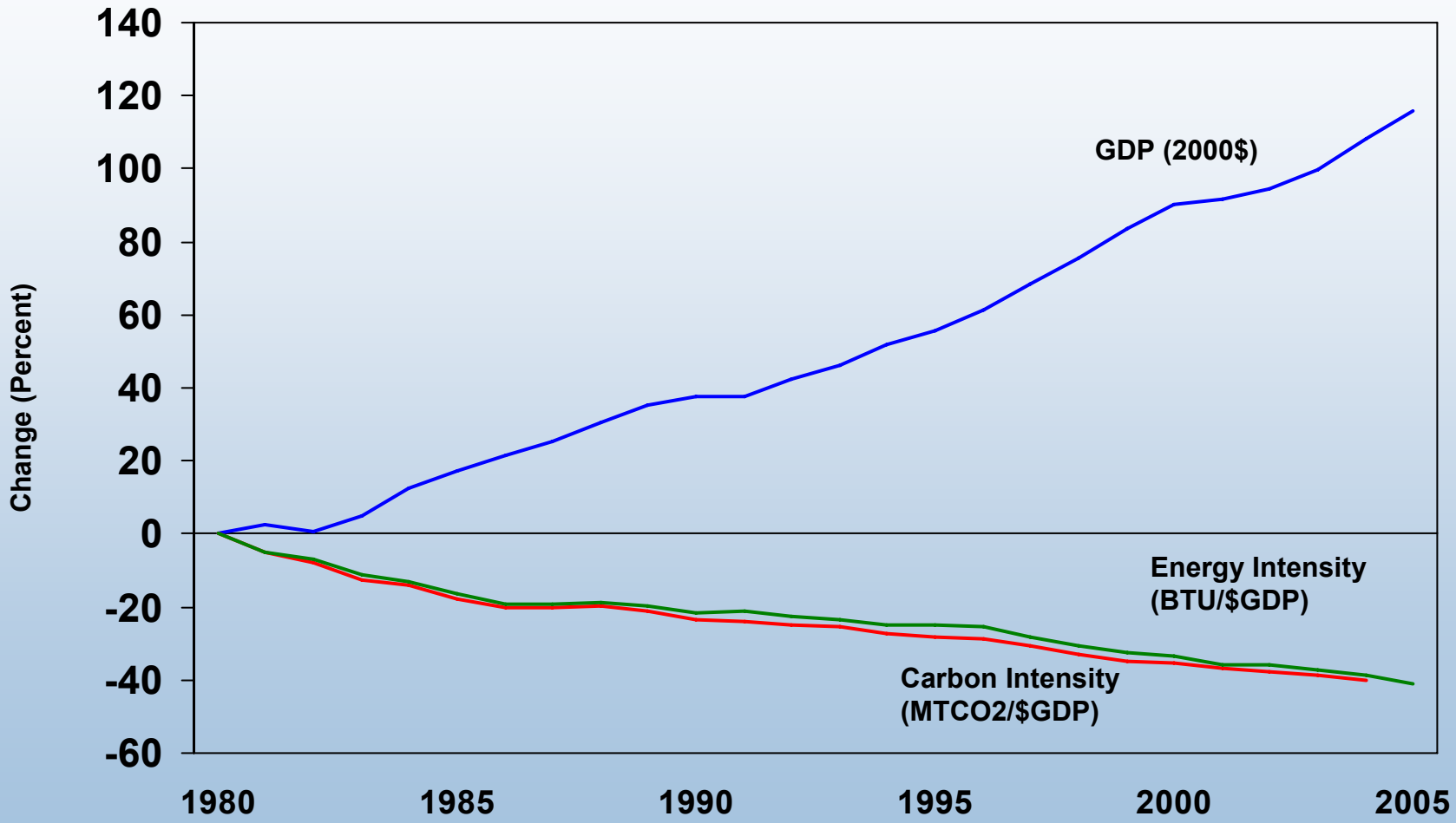
Source: Energy Information Administration, International Energy Annual 2000 Tables E1, B1, B2; Gross Domestic Product per capita is for 2000 in 1995 dollars. Updated May 2002

U.S. Energy Consumption and the Role of Renewable Energy



Source: Energy Information Administration, *Annual Energy Outlook 2006,* Table D4

Carbon and Energy Intensity



Source: Energy Information Administration, "Annual Energy Review 2005", DOE/EIA-0384(2005), Table 1.5

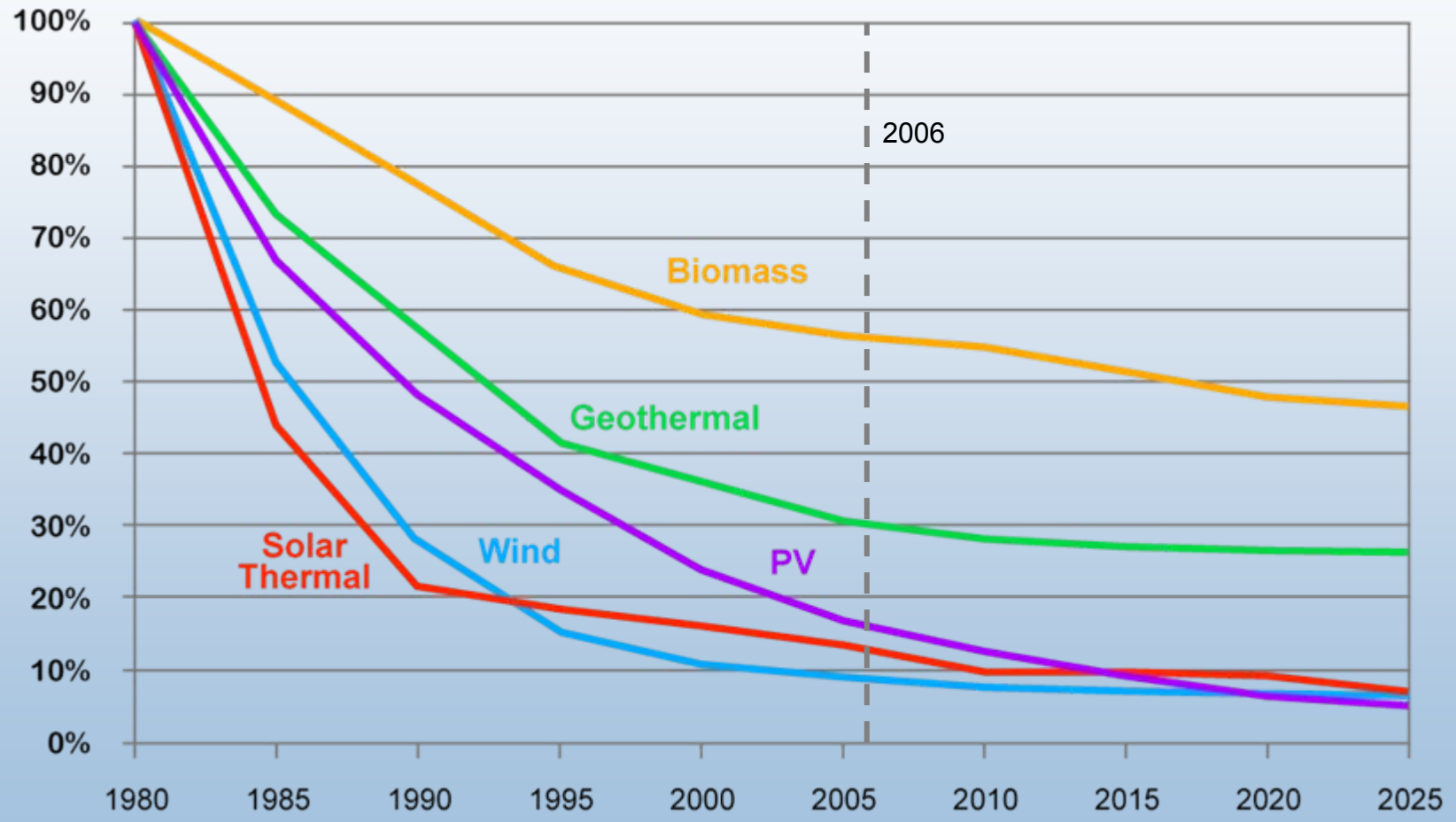
Technology-Based Solutions:

There is no single or simple answer

- Energy efficiency
- Renewable energy
- Nonpolluting transportation fuels
- Separation and capture of CO_2 from fossil fuels
- Next generation of nuclear fission and fusion technology
- Transition to smart, resilient, distributed energy systems coupled with pollution-free energy carriers such as hydrogen and electricity

Renewable Energy Costs Have Decreased

Historical and Projected

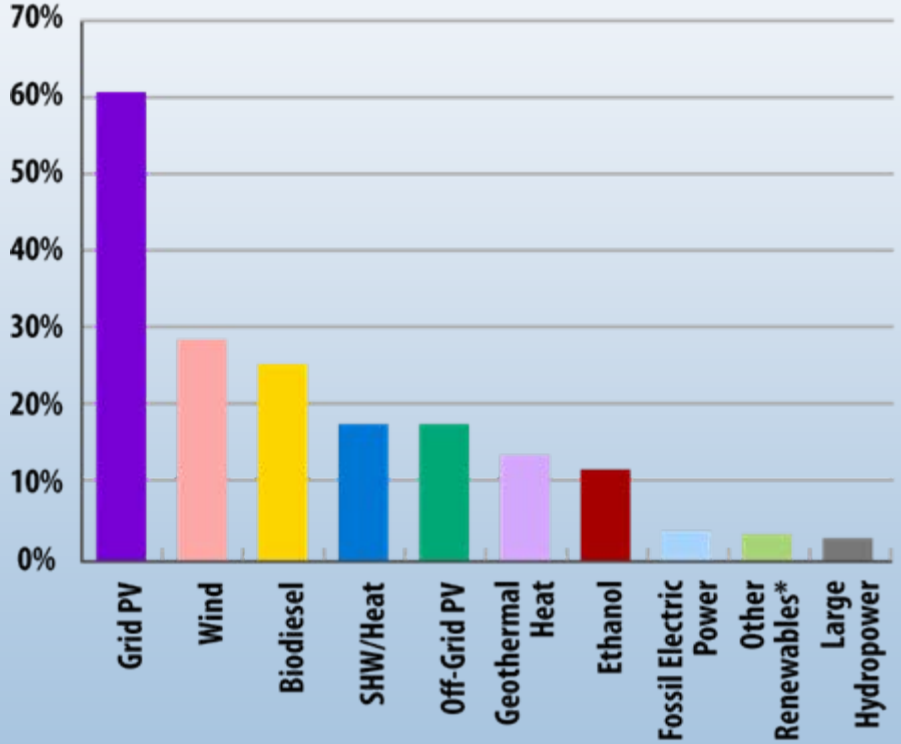


Costs as percentage of 1980 levels

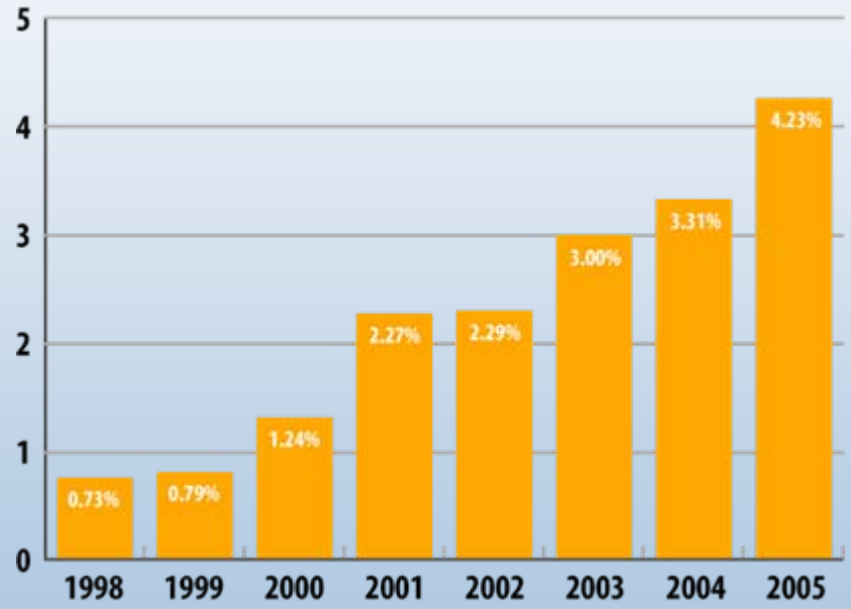
Source: NREL 2005, 2002

Renewable Energy Is Growing

Renewable Energy Annual Growth Rates 2000-2004



Energy-Tech Investments Percent of Total U.S. Venture Capital



Sources:
Renewables 2005 Global Status Report, REN21
Clean Energy Trends 2006, Nth Power LLC

Energy Efficiency and Renewable Energy Technology Development Programs

NREL R&D Portfolio

Efficient Energy Use

- Vehicle Technologies
- Building Technologies
- Industrial Technologies

Renewable Resources

- Wind
- Solar
- Biomass
- Geothermal

Energy Delivery and Storage

- Electricity Transmission and Distribution
- Alternative Fuels
- Hydrogen Delivery and Storage

Foundational Science

Solar Photovoltaics

Status:
- 450 MW
- Cost 18-23¢/kWh

Potential:
- 11-18¢/kWh by 2010
- 5-10 ¢/kWh by 2015

NREL Research Thrusts:
- Higher efficiency devices
- New nanomaterials applications
- Advanced manufacturing techniques

Source: U.S. Department of Energy, updated March 16, 2006

Wind

Today's Status

- 10,000 MW installed as of August 2006
- Cost 6-9¢/kWh at good wind sites

DOE Cost Goals

- 3.6¢/kWh, onshore at low wind sites by 2012
- 5¢/kWh, offshore in shallow water by 2014

Long Term Potential

- 20% of the nation's electricity supply

NREL Research Thrusts

- Low wind speed technology
- Distributed wind technology
- Advanced rotor development
- Utility grid integration

Updated September 7, 2006
Source: U.S. Department of Energy, American Wind Energy Association

Biofuels

Biofuels status

- Biodiesel – 75 million gallons (2005)
- Corn ethanol
  - 81 commercial plants
  - 3.9 billion gallons (2005)
  - Today's cost ~$1.35/gallon of gasoline equivalent (gge)
- Cellulosic ethanol
  - Projected commercial cost ~$3.00/gge

Potential

- 2012 goal – cellulosic ethanol ~$1.42/gge
- 2030 goal – all ethanol = 30% of transportation fuels

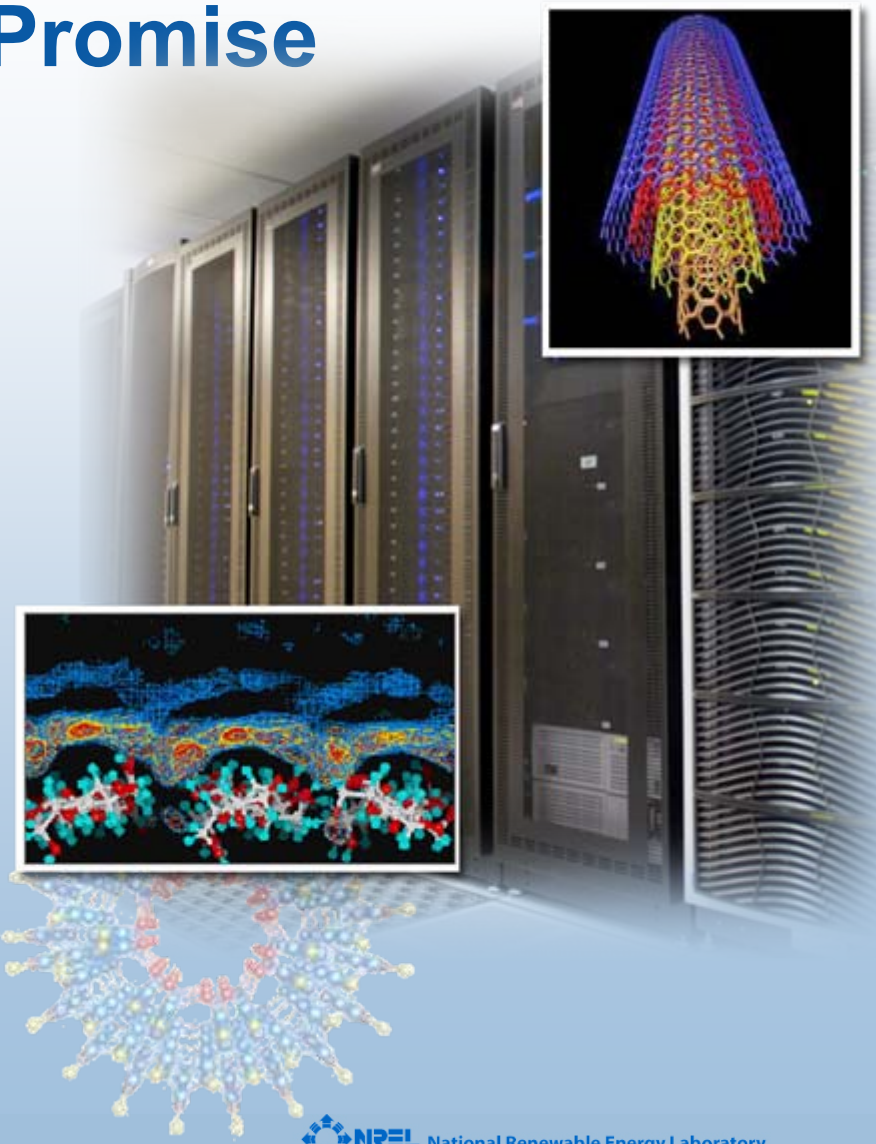
NREL Research Thrusts

- The Biorefinery
- Solutions to under-utilized waste residues
- Energy crops

Source: U.S. Department of Energy, National Biodiesel Board, Renewable Fuels Association

Harnessing Innovation in Renewable Energy Science and Technology: The Future Promise

- Supercomputers
- Genomics
- Nanoscience
- Cellulosic and biofuels applications
- Hydrogen



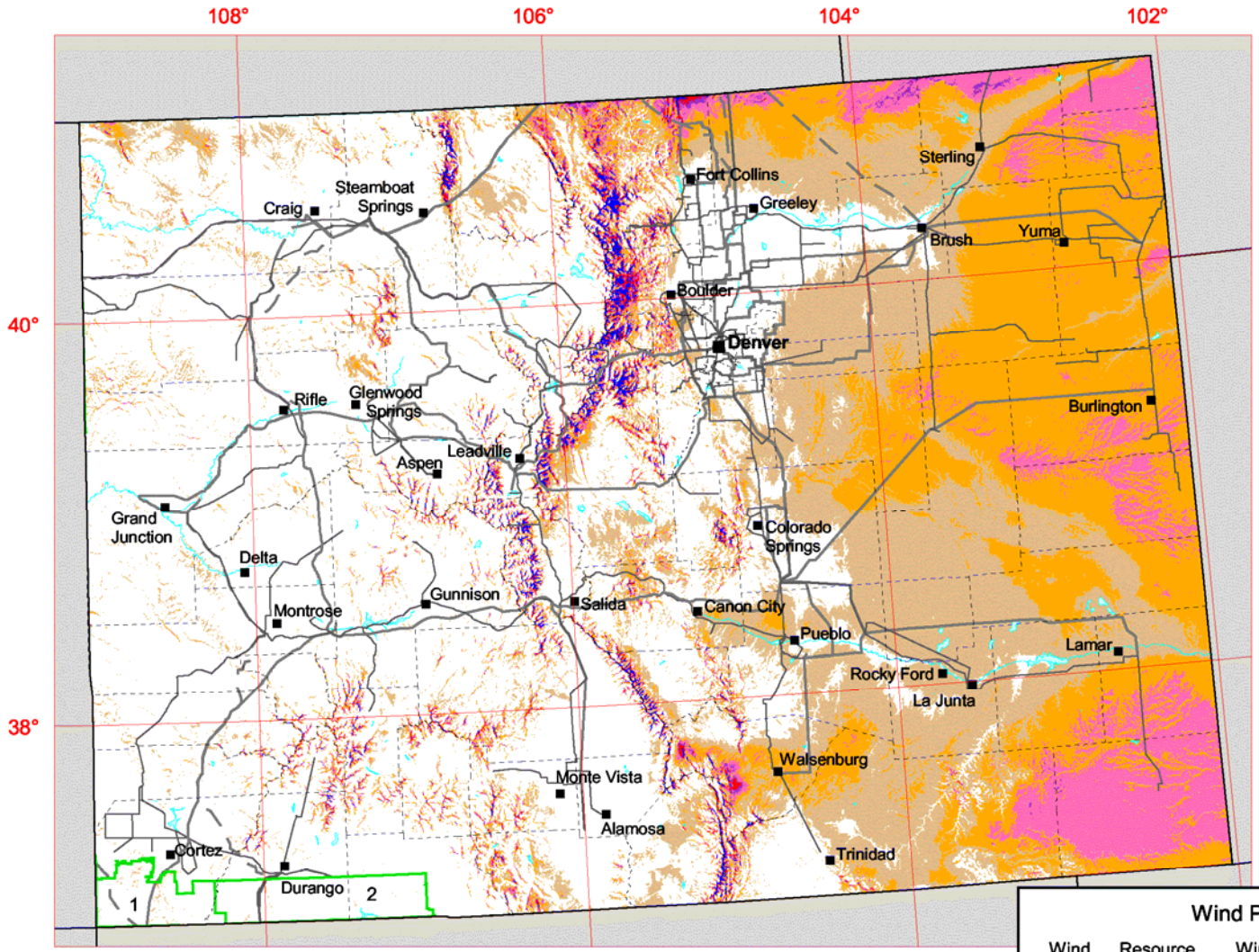
Nano/Bio/Info

NREL as a Resource for Economic Development

- Total FY05 Colorado contribution - $128 million
- Partnerships with Colorado universities
- Support for Colorado economic development community
- Education programs annually reach 25,000 teachers, students and consumers
- NREL and staff contributed $135,000 to local charitable organizations
- Underwrote and designed first-ever Net Zero Energy Habitat House in Wheat Ridge

Renewable Energy: Enabling Economic Growth in Colorado

- Plentiful resources
- Centers of Excellence
- Business environment



Colorado

50 m Wind Power

Transmission Line*
Voltage (kV)
115 - 161
230
345

* Source: POWERmap,©2003 Platts, a Division of the McGraw-Hill Companies

The annual wind power estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.

50 0 50 100 150 200 Kilometers
50 0 50 100 Miles

Indian Reservation
1 Ute Mountain
2 Southern Ute

Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
1	Poor	0 - 200	0.0 - 5.9	0.0 - 13.2
2	Marginal	200 - 300	5.9 - 6.7	13.2 - 15.0
3	Fair	300 - 400	6.7 - 7.4	15.0 - 16.6
4	Good	400 - 500	7.4 - 7.9	16.6 - 17.7
5	Excellent	500 - 600	7.9 - 8.4	17.7 - 18.8
6	Outstanding	600 - 800	8.4 - 9.3	18.8 - 20.8
7	Superb	> 800	> 9.3	> 20.8

[a] Wind speeds are based on a Weibull k of 2.0 at 1500 m elevation.

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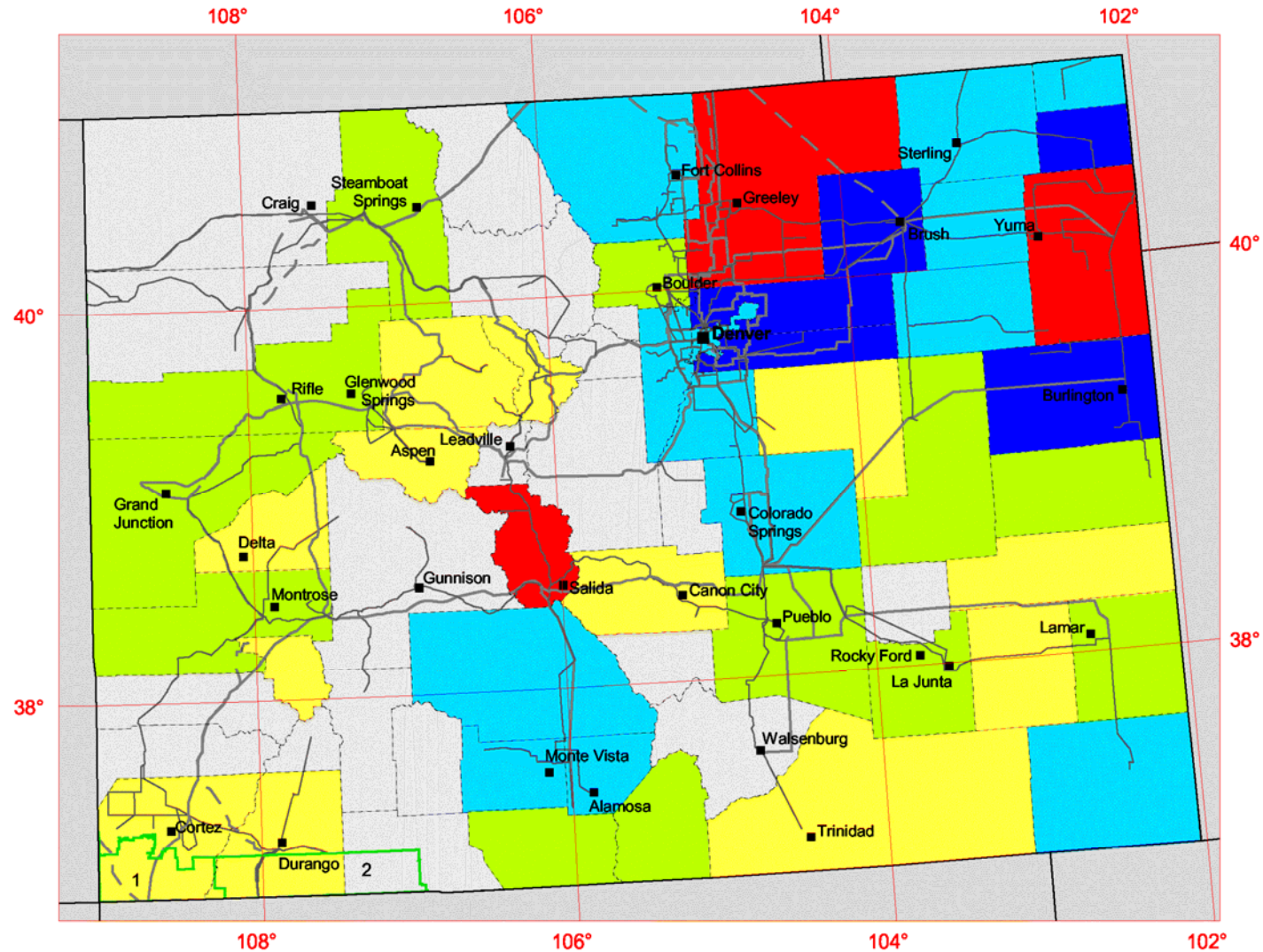

Colorado

Biomass Resource

Thousand Tonnes/Year

- > 150
- 100 - 150
- 50 - 100
- 10 - 50
- 5 - 10
- 0 - 5

This study estimates the technical biomass resources available in the United States by county, based on one year of production. It includes the following feedstock categories:

- Agricultural residues (crops and animal manure);
- Wood residues (forest, primary mill, secondary mill, and urban wood);
- Municipal discards (methane emissions from landfills and wastewater treatment plants);
- Dedicated energy crops (on Conservation Reserve Program and Abandoned Mine Lands).

This data is still under review by NREL.

Transmission Line*
Voltage (kV)
- 115 - 161
- 230
- 345

* Source: POWERmap,©2003 Platts, a Division of the McGraw-Hill Companies

Indian Reservation
- 1 Ute Mountain
- 2 Southern Ute

50 0 50 100 150 200 Kilometers
50 0 50 100 Miles

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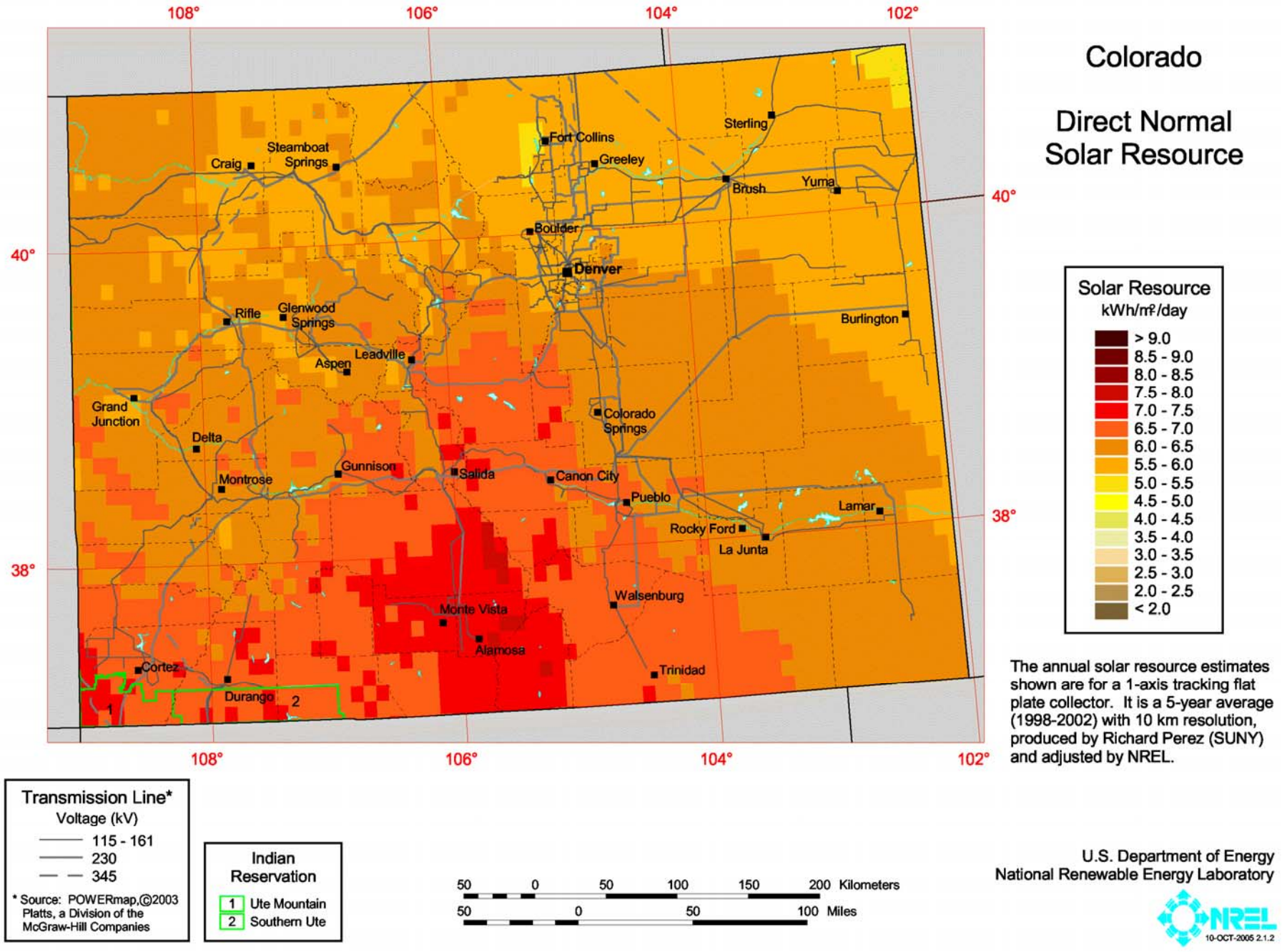
NREL
11-OCT-2005 2.1.4



The annual solar resource estimates shown are for a 1-axis tracking flat plate collector. It is a 5-year average (1998-2002) with 10 km resolution, produced by Richard Perez (SUNY) and adjusted by NREL.

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10-OCT-2005 2.1.2

Renewable Energy: Getting There Involves…

Technologies
- Efficient buildings and vehicles
- New biofuels
- Clean generation
- Storage

Reducing Risk

Mobilizing Capital

Policies
- Predictable and consistent

Markets
- Infrastructure
- First plant costs
- Supplier/consumer acceptance


The U.S. Department of Energy's
National Renewable Energy Laboratory
www.nrel.gov
Golden, Colorado